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L. Kleinrock and F. Tobagi
UCLA
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Routing in Packet Radio Systems
Controlled Flooding using Handover Numbers

The system under study here consists of the three elements: stations, repeaters and terminals. In our model, each station is assigned a region in which repeaters are uniformly spread, covering the entire region. It will be assumed that all packets originated in a given region will be directed to the station assigned to that region.

The uniform organization is helpful when one is seeking mathematical or simulation results. The station is assumed to be at the center of the region. Each repeater is equidistant to its nearest neighbors. There are only three uniform structures which tessalate the plane: the square grid, where n, the number of neighbors, is 4; the hexagonal (bee hive) structure with $n = 3$; and the triangular structure with $n = 6$. In the following, we will be mainly considering the square grid organization, but the concepts introduced are applicable to the two others.

One more assumption is made: the capture phenomenon is assumed to be such that when a repeater transmits a packet, only its nearest neighbors are capable of receiving it correctly (in the case of no conflicts).

A numbering scheme

Let us consider for the time being, the routing of a packet from the terminal to the station. If, everytime a repeater receives a packet correctly, we let it retransmit the packet, the system will rapidly be flooded, and useless copies of a packet will remain.

On the other hand, if we let a fixed single path handle packets between a repeater and the station, then the reliability of the system is poor and the system would not be able to dynamically adjust its routes.

The following numbering scheme will allow a kind of controlled flooding of the system by the many copies of a transmitted packet:

- A repeater can distinguish between a (new) packet transmitted by a terminal and a (repeated) packet relayed by a repeater.

- Each repeater R_i is assigned a number N_i equal to its (Hamming) distance to the station, i.e., the minimum number of hops between the repeater and the station (see Figure 1)

• When repeater R_i receives a new packet, it assigns to it a hand-over number M whose value is chosen such that $M \geq N_i$. R_i then transmits the packet decreasing M by 1.

• When repeater R_j receives a relayed packet, a check is made on the current value of the hand-over number M: if $M < N_j$, R_j destroys or ignores the packet. (Transmitting it would be wasteful since, decreasing M at each transmission, M will reach the value 0 before reaching its destination (the station) and will have to be destroyed then). If $M \geq N_j$, R_j transmits the packet (if correctly received), decreasing M by 1.

The value of M limits the number of distinct repeaters that will handle a packet originated at some point in the region; specifically, when a repeater transmits a packet with a hand-over number of value m, then only neighboring repeaters with a distance $N_i \leq m$ will take the packet into consideration and all other neighbors will ignore it.

It is easy to see that the larger the initial value assigned to M (by a repeater receiving the new packet), the larger is the number of distinct repeaters that will handle the packet, and hence the larger is the number of alternative routes that the packet will take from the terminal to the station.

An illustration of this scheme is given in Figure 2. In this example we focus on repeater R whose distance is 5. Assume R receives a packet with a number $M \geq 5$. Several contours are sketched, corresponding to different values of M, limiting sub-regions of repeaters that will handle the packet.

We note that the larger the contour is, the larger is the rate of packets handled by each repeater and hence the higher is the probability of conflicts between any pair of repeaters; at the same time, more alternate paths to the station are available. For example, if the initial value assigned to M by each repeater R_i is equal to N_i, then repeater R in Figure 1 will handle all traffic originated in the shaded area.

It is not yet clear what value one should initially assign to M, and whether this controlled flooding scheme should be used all the time or not.

We feel that a combination of controlled flooding and single routes from a given repeater to the station might be advantageous: every so often, the repeater will flood the system with a packet <u>searching</u> for a path; the latter will be the path corresponding to the <u>first</u> copy of the packet reaching the station (lowest delay), and will be used in consequent transmissions for a certain period of time. Since we have little feeling about how long that period of time should be, we are thinking of <u>randomizing</u> the process in the following way: when transmitting a packet, a repeater will flood the system with a probability p, and will use the latest path found with probability $1-p$. A value of p is felt to exist which minimizes the delay in the system, and this optimal value of p will be dependent upon the requirements the system is to satisfy.

A simulation model will be used to investigate the above scheme.

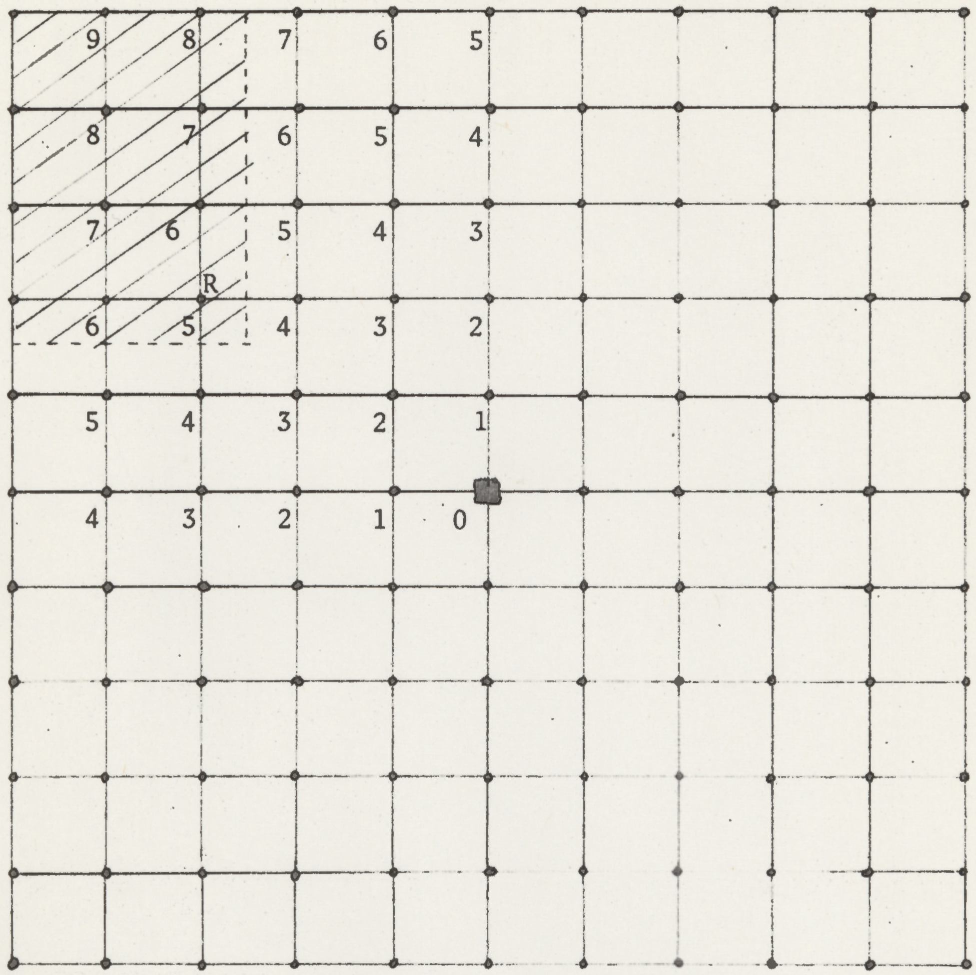

Figure 1

Numbers N_i assigned to repeaters. Repeaters designated by (•) and station by (■).

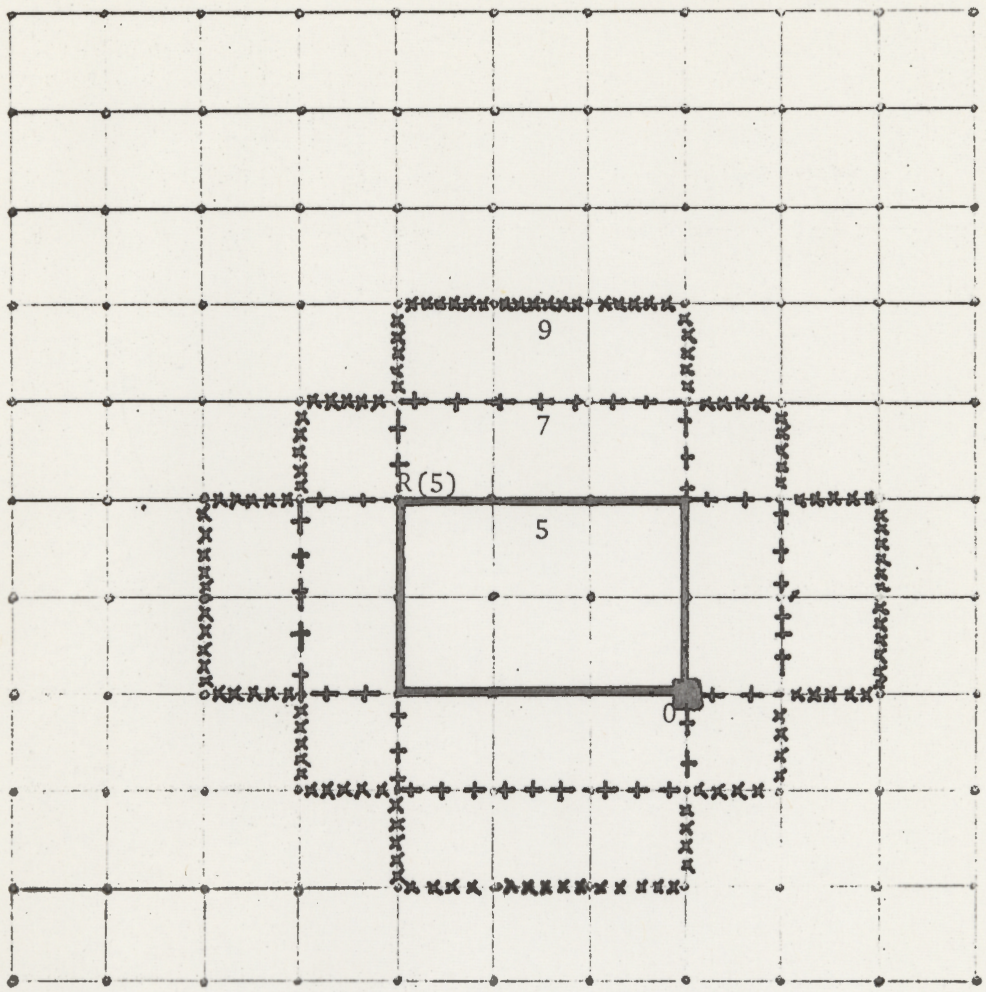

Figure 2

Contours corresponding to different initial values for M

______ initial value 5

++++++ initial value 7

xxxxxx initial value 9